Considerations on the Natural Seasonal Thermal Pattern

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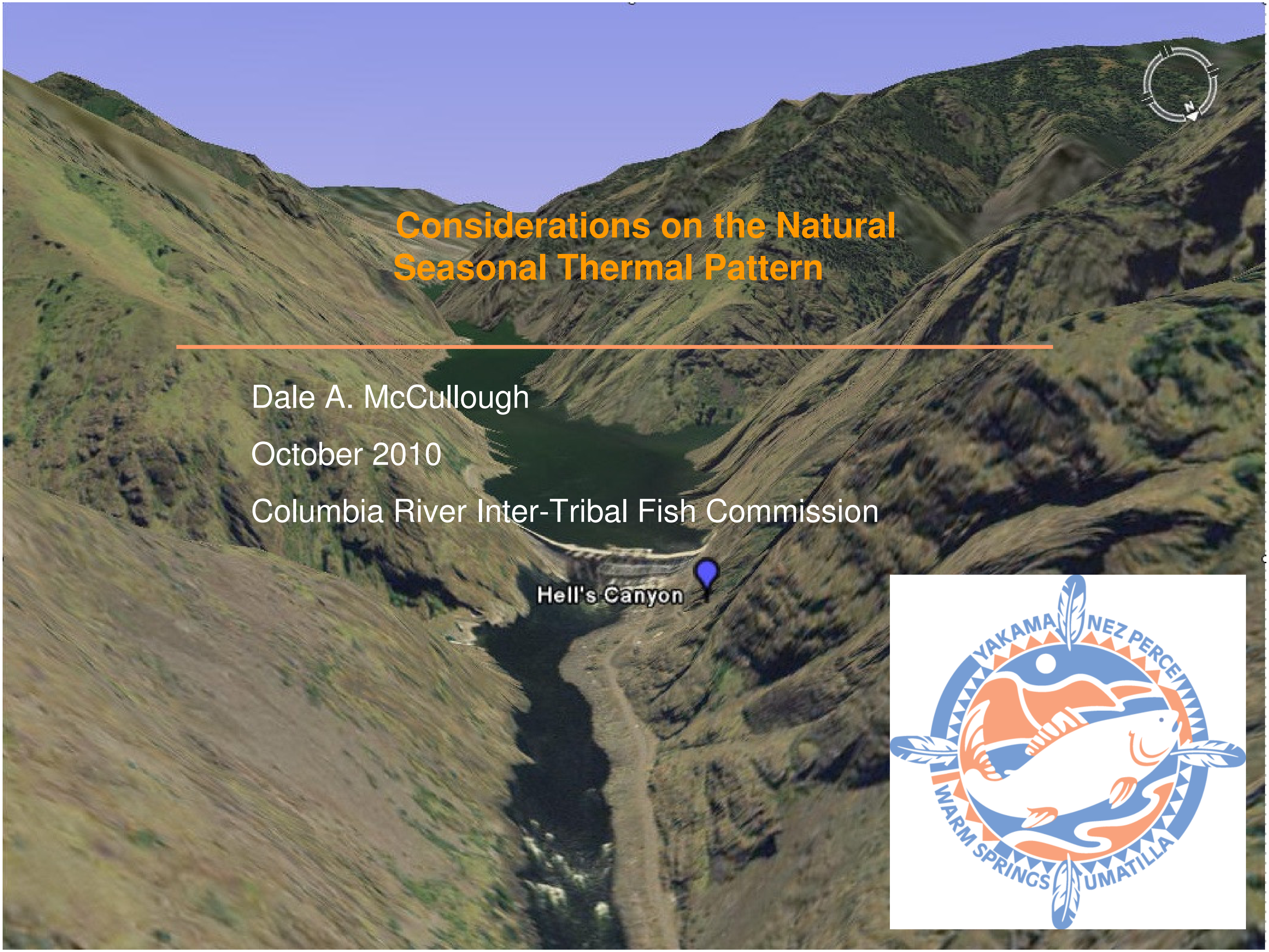
Columbia River Inter-Tribal Fish Commission



Water Temperature Trends

The water temperature trends for the Columbia River have shown a steady increase from 1938 to 1997 of 0.039˚C per year (NPCC 2004) at Bonneville Dam. Between 1938 and 1997 there has been approximately a 1.67˚C increase in Columbia River water temperatures.

Progressive water temperature increases have been observed across the United States, so rather than being a speculative matter, this is a major environmental impact that salmon runs have had to contend with. The impacts of climate change have already been suffered by northern California salmon runs (Williams 2006). The ability to accommodate further changes in either maximum temperatures or shifts in thermal regime are limited by the species' behavioral and genetic plasticity (Myrick and Cech .

Recently Kaushal et al. (2010) reported that 50% of rivers they surveyed in the United States showed significant long-term upward trends (0.009–0.077℃/year) in water temperatures linked to increasing air temperature. They cautioned that "If stream temperatures were to continue to increase at current rates, due to global warming and urbanization, this could have important effects on eutrophication, ecosystem processes such as biological productivity and stream metabolism, contaminant toxicity, and loss of aquatic biodiversity.

Further, Williams (2010) argues that the prolongation of adverse water temperature regimes in the Snake River below Hells Canyon dam would subject the fall Chinook to a likely erosion in "genetic diversity, fitness, and resilience."

Kaushal, S.S., G.E. Likens, N.A. Jaworski, M.L. Pace, A.M. Sides, D. Seekell, K.T. Belt, D.H. Secor, and R.L. Wingate. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment

Myrick, C.A. and J.J. Cech, Jr. 2001. Temperature Effects on Chinook Salmon and Steelhead: a Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum. Technical Publication 01-1. Available at http

NPCC. 2004. Lower Columbia Salmon and Steelhead Recovery and Subbasin Plan.
Williams, J.G.. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science. Vol. 4, Issue 3 (December 2006), Article 2. http://repositories.cdlib.org/jmie/sfews/vol4/iss3/art2).

Williams, R.N. 2010. Review of Idaho Power Company's Proposed Temperature Mitigation Projects Related to the Hells Canyon Complex (HCC). Prepared for Idaho Rivers United and American Rivers. 27p.

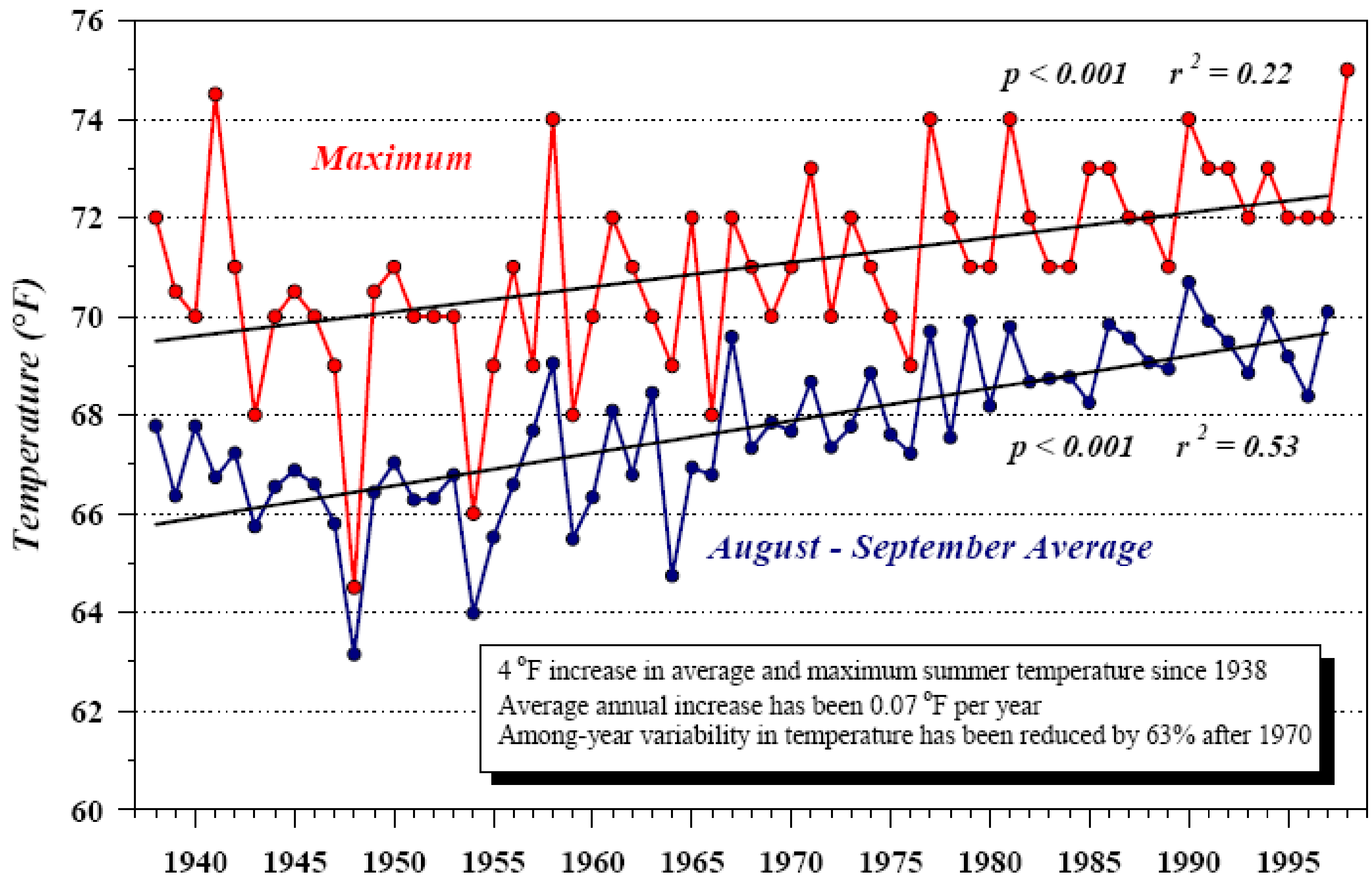


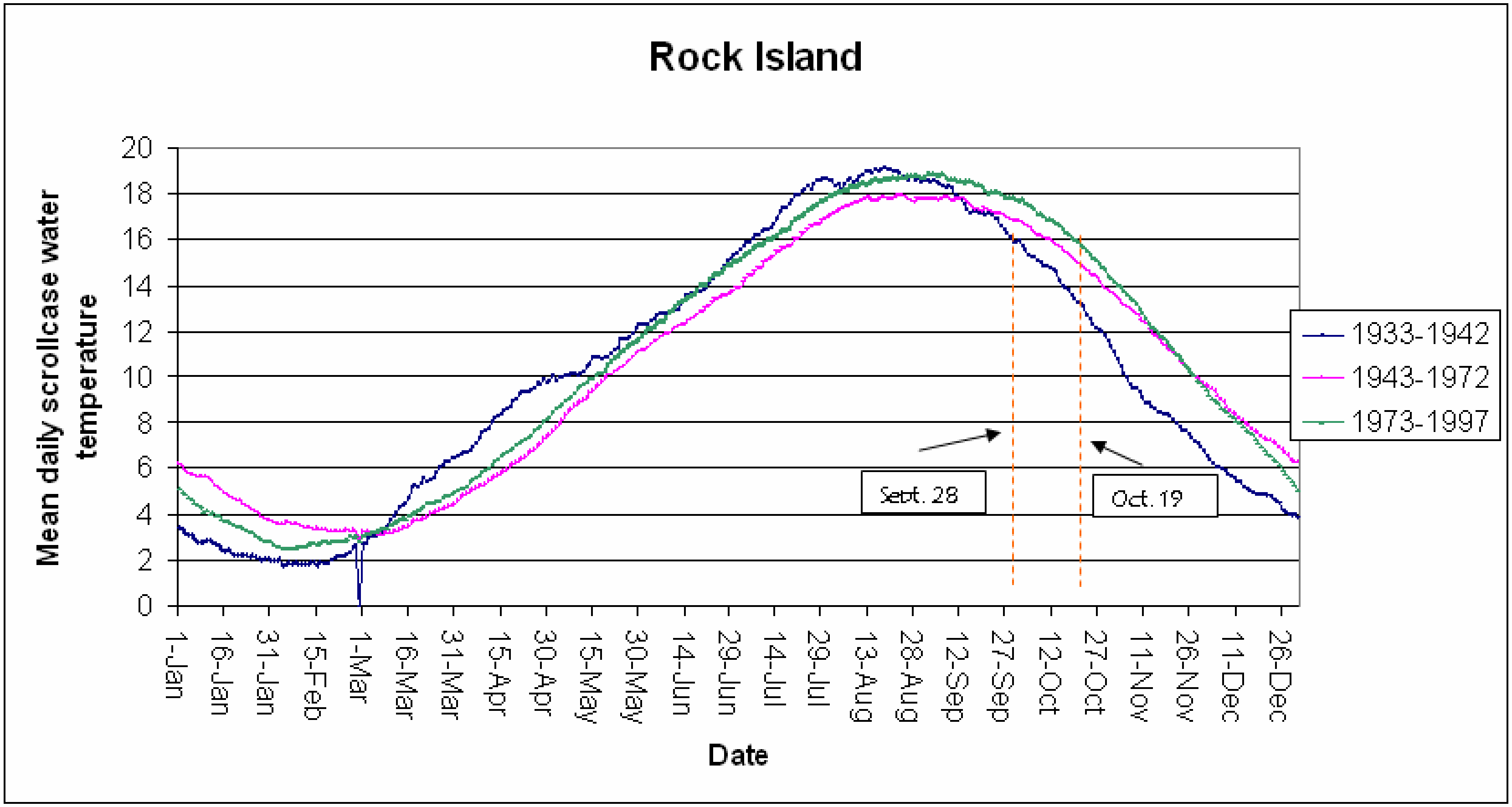
Figure 3-99. Historical changes in summer water temperatures at Bonneville Dam.

Source: NPCC. 2004. LOWER COLUMBIA SALMON AND STEELHEAD RECOVERY AND SUBBASIN PLAN

Thermal Shift in the Columbia River

Columbia River water temperatures at Rock Island Dam measured in the dam scroll case reveal a long-term pattern of shift in the thermal regime. These temperatures were segregated by date to reveal the changing pattern. Dates examined are 1933-1942, 1943-1972, and 1973-1997.

The date on first reaching a water temperature of 16˚C was September 28 in 1933-1942, but this was extended to October 19 based on the 1973-1997 record. This is a shift in the natural pattern by approximately 22 days. Because salmon cannot successfully spawn until appropriate water temperatures are achieved, the Columbia River fall Chinook would have to adjust their spawn timing or suffer increased mortality in pre-spawning adults or incubating eggs.



See file: Rock Island scroll case temperatures-1933-1997.doc

Thermal Shift in the Snake River

Snake River water temperatures can be contrasted between the USGS gauge at Weiser, Idaho (upstream of Brownlee Reservoir) and a point 10 miles downstream of Hells Canyon Dam. Although water temperature data collection has been spotty and inconsistent despite the level of hydropower development in the area, the shift in the thermal pattern is still obvious.

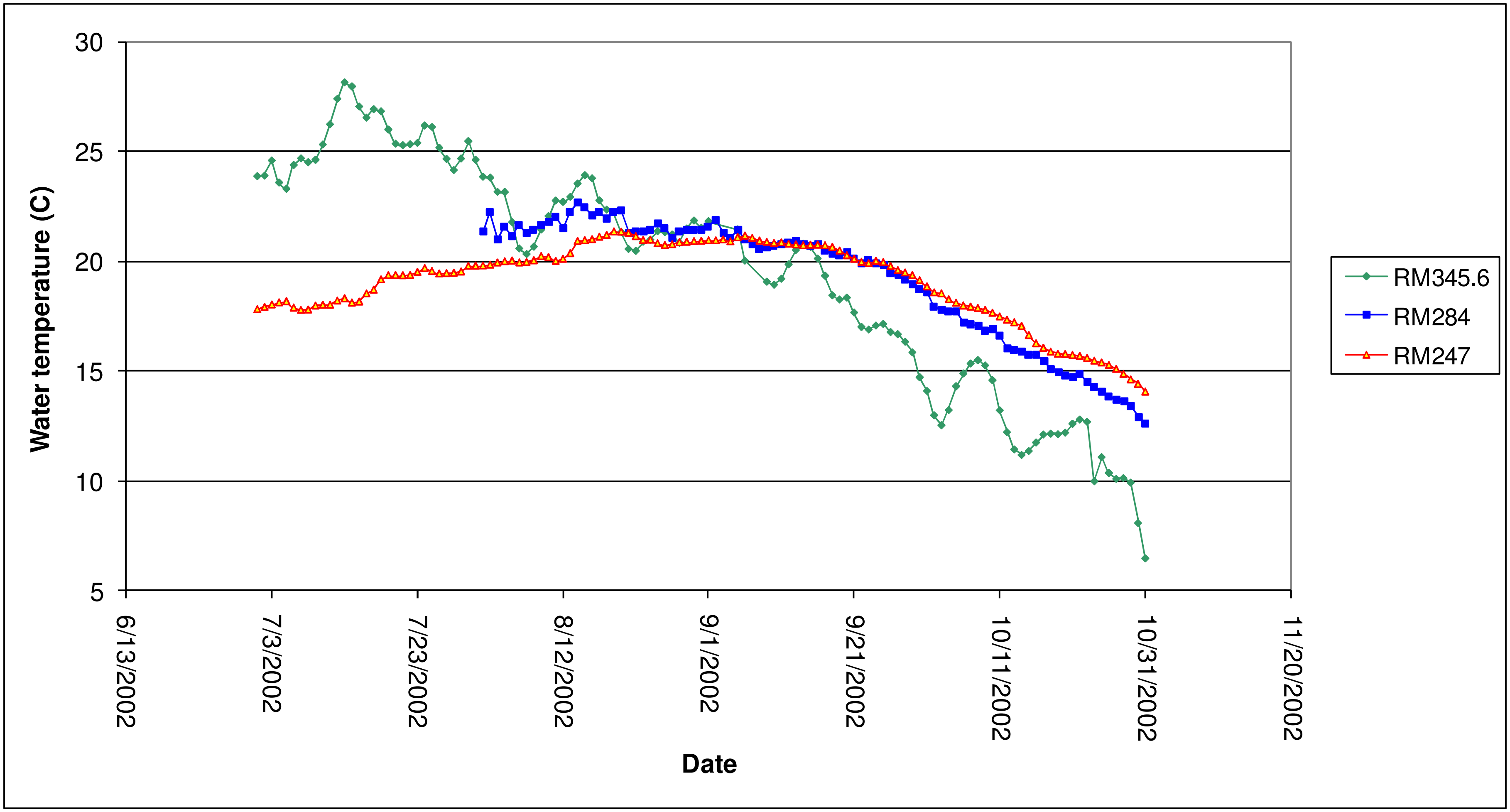
As in the Columbia River example, the date on first reaching a water temperature of 16˚C in a declining temperature period (September-October) was examined. This reveals that there is on average a 25-day shift in the timing of passing this temperature. That is, water temperatures below the dam achieve 16˚C 25 days later than they do above the Hells Canyon complex. Clearly, the presence of the dams causes this thermal shift. Again, the fall chinook would be forced to alter their spawn timing to accommodate the change to the thermal pattern because the temperature of optimal spawning and incubation survival is fixed, while the timing of the temperature decline has been shifted to later in the season.

Site	Date on first reaching 16° C	Day Number
10-mi downstream of HCD	Oct. 24, 1991	297
	Oct. 25, 1992	299
	Oct. 21, 1993	294
	Oct. 22, 1994	295
Mean		**296.3**
Snake River at USGS Weiser gage	Oct. 2, 1967	275
	Sept. 19, 1968	263
	Oct. 1, 1969	274
	Sept. 13, 1970	256
	Sept. 16, 1971	259
	Oct. 2, 1972	276
	Oct. 3, 1974	276
	Oct. 7, 1975	280
	Oct. 3, 1976	277
	Sept. 18, 1978	261
	Oct. 11, 1979	284
	Oct. 10, 1980	284
	Sept. 21, 1981	264
	Sept. 27, 1999	270
	Sept. 30, 2002	273
Mean		**271.5**

Thermal Shift in the Snake River (cont.)

Temperatures in the Snake River at Weiser begin declining in mid-July, but the water temperatures below Hells Canyon Dam (RM247) continue to increase until early October and then slowly decline. By late October the water temperatures remain higher than the inflow temperatures to Brownlee Reservoir. By October 23 the water temperatures below Hells Canyon Dam were still at least 3˚C warmer than the inflow temperatures.

Snake River Water Temperatures for 2002
Below Hells Canyon Dam (RM247) and near Weiser River (RM345.6)



SR-HCtemperaturedataforDMcCulloughCRITFC.xlsx (data supplied by T. Dombrowski)

Thermal Pattern in the Snake River (cont.)

The initiation of the fall Chinook adult upstream migration begins officially at Bonneville Dam on August 1. The current peak of water temperatures in the Snake River below Hells Canyon Dam occurs on approximately August 23 every year. According to data from the Snake River TMDL the maximum daily water temperatures on October 23 range from approximately 13˚C to 16˚C.

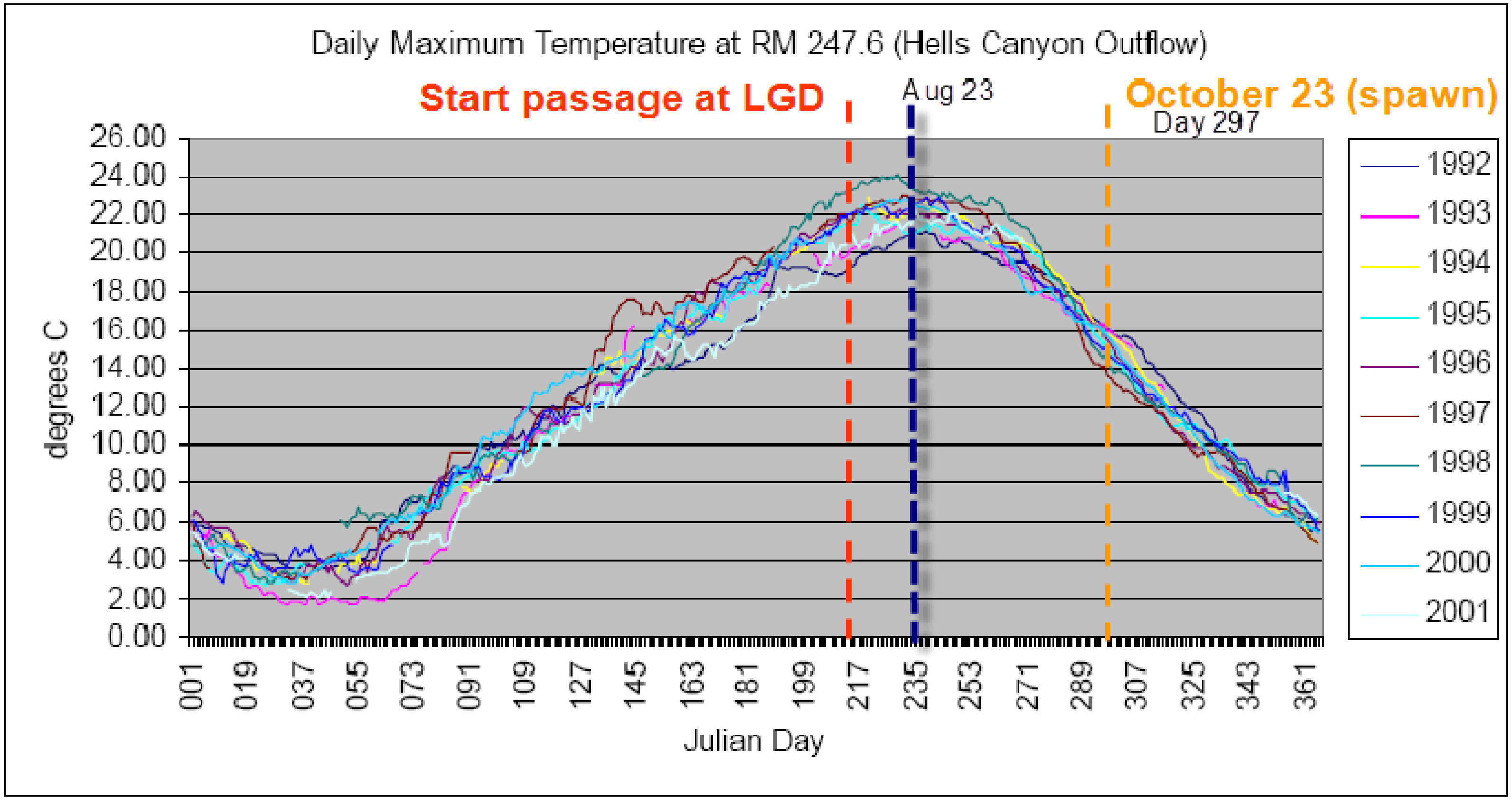


Figure 3.6.2 e. Water temperatures for the Downstream Snake River segment (RM 247 to 188) of the Snake River - Hells Canyon TMDL reach near Hells Canyon Dam.

Chart from Snake River TMDL

Thermal Pattern in the Snake River (cont.)

The sharp contrast between the thermal patterns expressed in the reservoir inflow water temperatures vs. the Hells Canyon Dam outflow temperatures reveals the current thermal shift that has occurred.

The same shift in timing of the temperature decline can be seen by looking at the water temperatures below Hells Canyon Dam at the Central Ferry location. The peak temperature in 1958 was reached by late July, after which temperatures declined.

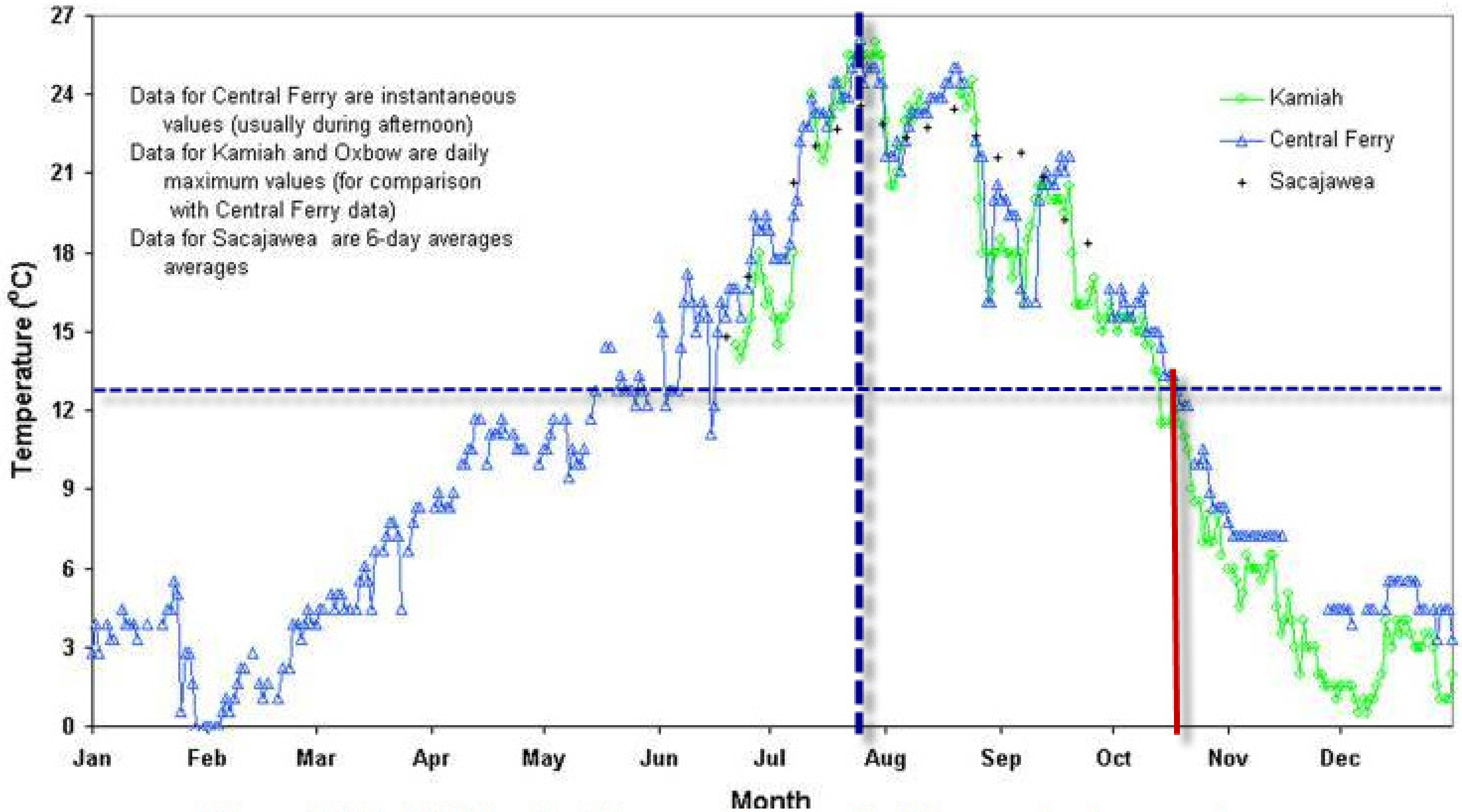


Figure 5.4-7. 1958 Snake River and Clearwater River water temperatures

Oxbow (approximately 130 miles upstream of the confluence), and for the Clearwater River at Kamiah (approximately 69 miles upstream of the confluence).

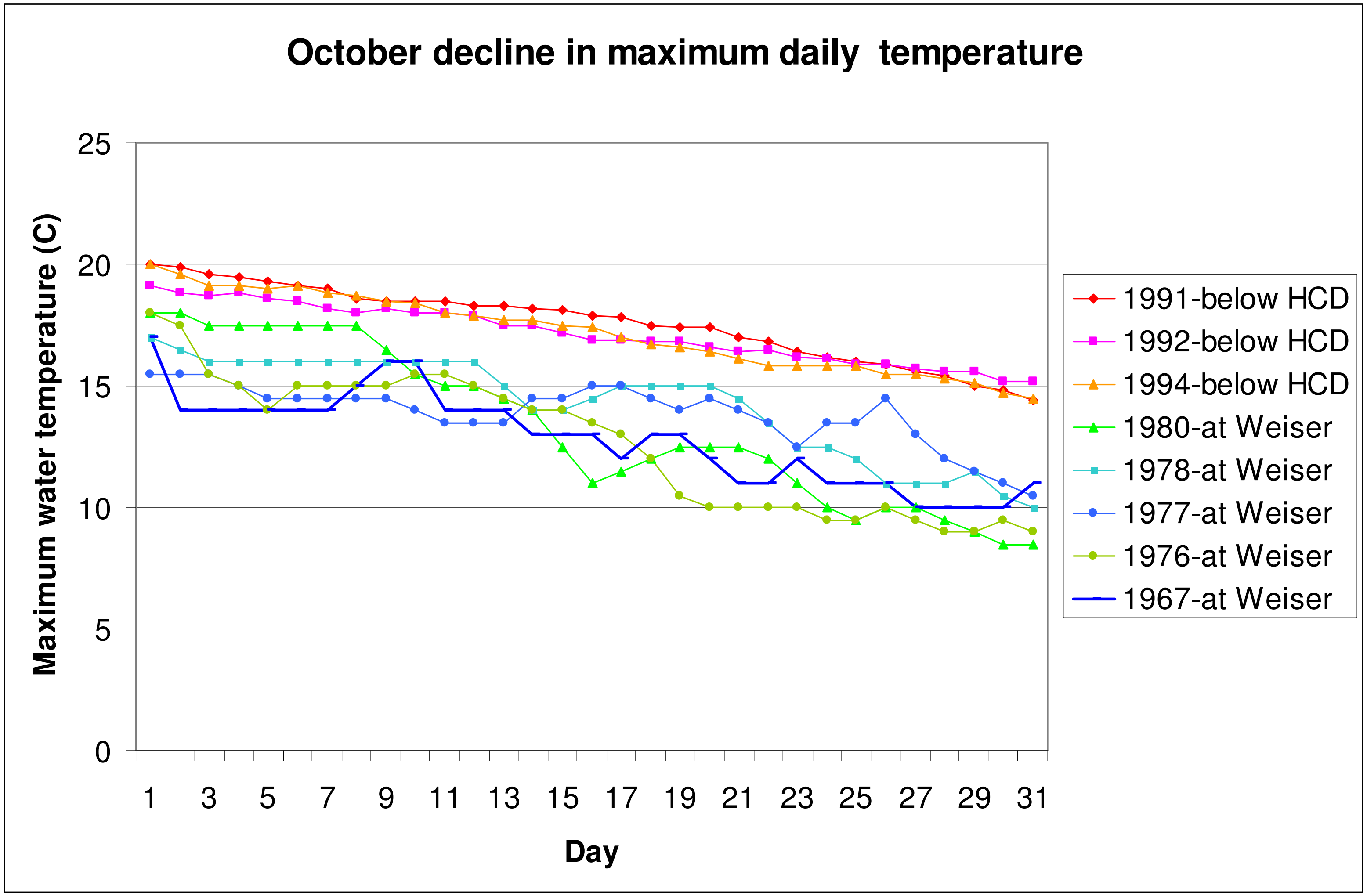
USACE. 1999. Lower Snake River Water Quality and Post-Drawdown Temperature and Biological Productivity Modeling Study. US Army Corps of Engineers, Walla Walla District. 323 p. http://www.nww.usace.army.mil/lsr/reports/water_quality/model.htm

Thermal Pattern in the Snake River (cont.)

Under current conditions, water temperatures decline during October in the Snake River below Hells Canyon Dam but in 1991, 1992, and 1994, water temperatures still remained above 16˚C by October 23.

In contrast, the water temperatures at Weiser, Idaho on the Snake River (i.e., above Brownlee Reservoir) were consistently 2 to 5˚C cooler. The reservoir system produced by the Hells Canyon Complex results in very prolonged cooling rates.

Comparison of the rate of decline in maximum water temperature in the Snake River measured at the Weiser gage and at a station 10 miles downstream of Hells Canyon Dam.



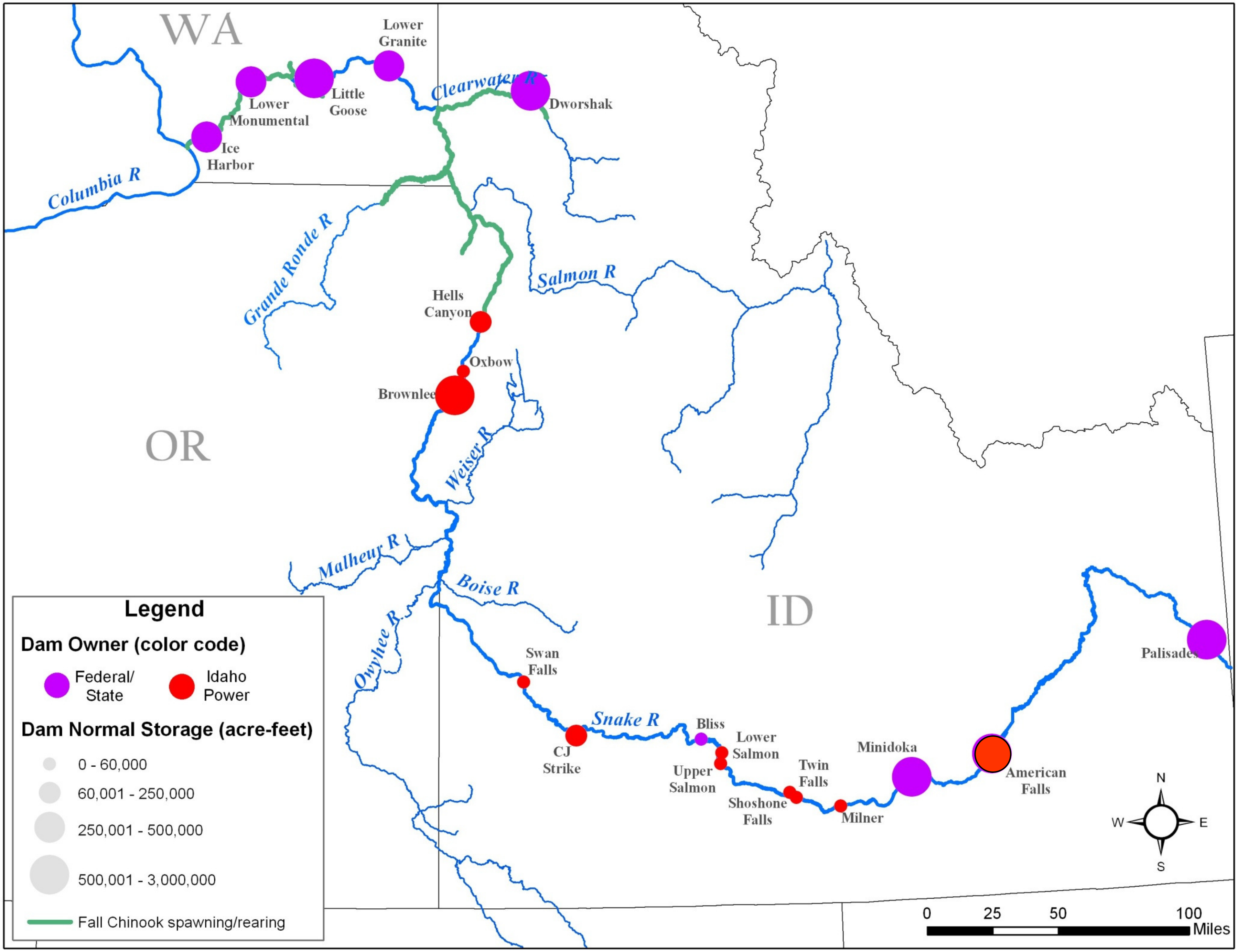
See file:Water temperature-Weiser vs below HCD-October.doc

Thermal Pattern in the Snake River (cont.)

A water temperature standard of 20˚C was set by Oregon as a protective standard for the mainstem Columbia and Snake Rivers. The effectiveness of this standard was seen as dependent upon the existence of thermal refugia in the mainstem to aid salmon in their upstream migration and holding prior to spawning.

Although it is recognized that maximum daily water temperatures were above 20˚C during parts of July in the 1950s, the Snake River mainstem had already been heavily affected by hydropower development and mainstem reservoirs. Much of this development started in the early 1900s and was also controlled by Idaho Power Company. Oregon has a provision to modify a water temperature standard to correspond to the natural background in cases where the proposed standard is higher than natural. In the case of the Snake River, the water temperatures observed in the 1950s were in no way natural.

The harm caused by the current water temperature regime stems from the prolongation of high temperatures late in the summer/fall period when adult fall chinook are holding prior to spawning. This subjects holding adults to prolonged exposure to adverse temperature conditions that can increase mortality due to a combination of disease, gamete impairment, excessive delays in reproduction, and bioenergetic stress. Current mainstem water temperatures are also minimally variable from day to day, so when high temperatures are reached, there are no opportunities for biological recovery that might occur from one day to the next. A natural thermal regime that has greater inter-day variation provides adults some recovery time when temperature spikes occur.


WA
OR
ID
Lower Granite
Little Goose
Lower Monumental
Ice Harbor
Clearwater R
Dworshak
Columbia R
Grande Ronde R
Salmon R
Hells Canyon
Oxbow
Brownlee
Weiser R
Malheur R
Boise R
Owyhee R
Swan Falls
Snake R
CJ Strike
Bliss
Lower Salmon
Upper Salmon
Twin Falls
Shoshone Falls
Milner
Minidoka
American Falls
Palisades
Legend
Dam Owner (color code)
Federal/ State
Idaho Power
Dam Normal Storage (acre-feet)
0 - 60,000
60,001 - 250,000
250,001 - 500,000
500,001 - 3,000,000
Fall Chinook spawning/rearing
N
W
E
S
0
25
50
100
Miles

Spawn Timing

Even though water temperatures in the 1950s, as recorded at Central Ferry on the Snake River mainstem (21 km upstream from Little Goose Dam) were relatively high (USACE 1999), reaching peaks of 25 to 26˚C between 1956 and 1958), these peaks temperatures were not sustained the same way that temperatures are with an immediate upstream reservoir effect, and inter-day variation was considerable.

In 1947, fall chinook spawning between Swan Falls and Marsing occurring between September 30 and October 17 was a significant proportion of the entire distribution (Zimmer 1950). This was prior to the development of the Hells Canyon Complex. On the other hand, between 1991 and 1995 spawning commenced essentially around October 23 (Rondorf and Tiffan 1997).

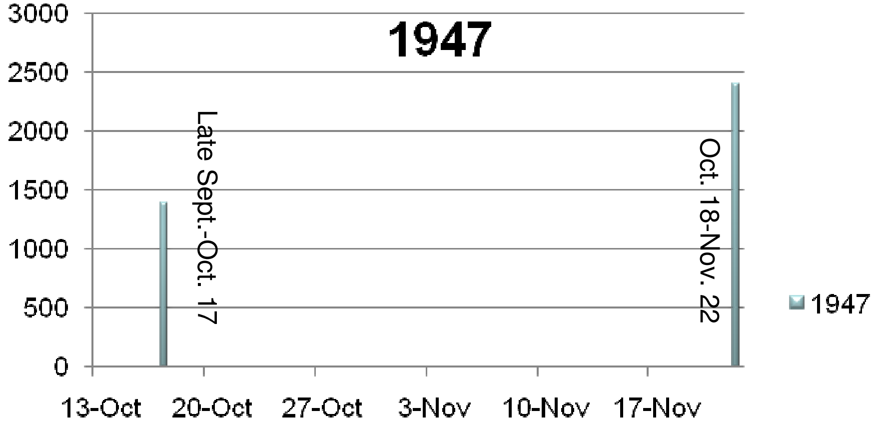
The ability of fall chinook to spawn earlier when water temperatures are colder can be witnessed in the Clearwater River.

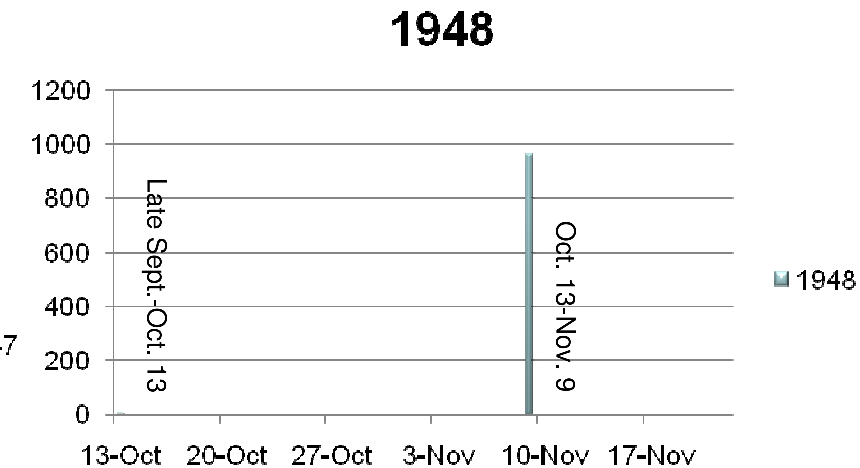
Rondorf, D.W. and K.F. Tiffan. 1997. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Bonneville Power Administration, Division of Fish and Wildlife, Lower Snake River Compensation Plan Office, U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project No. 91-029, Contract No.DE-AI79-91BP21708, (BPA Report DOE/BP-21708-1) 112 electronic pages

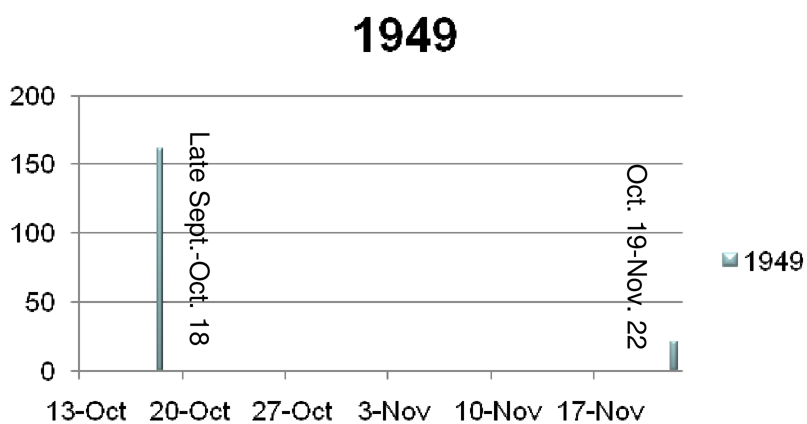
USACE. 1999. Lower Snake River Water Quality and Post-Drawdown Temperature and Biological Productivity Modeling Study. US Army Corps of Engineers, Walla Walla District. 323 p. http://www.nww.usace.army.mil/lsr/reports/water_quality/model.htm

Zimmer, P.D. 1950. A Three Year Study of Fall Chinook Salmon Spawning Areas in the Snake River Above Hells Canyon Dam Site. Supplements in 1951 and 1953. U.S. Fish and Wildlife Service Report.

Distribution of Fall Chinook Redds [1]Observed by Plane From Swan Falls to Marsing





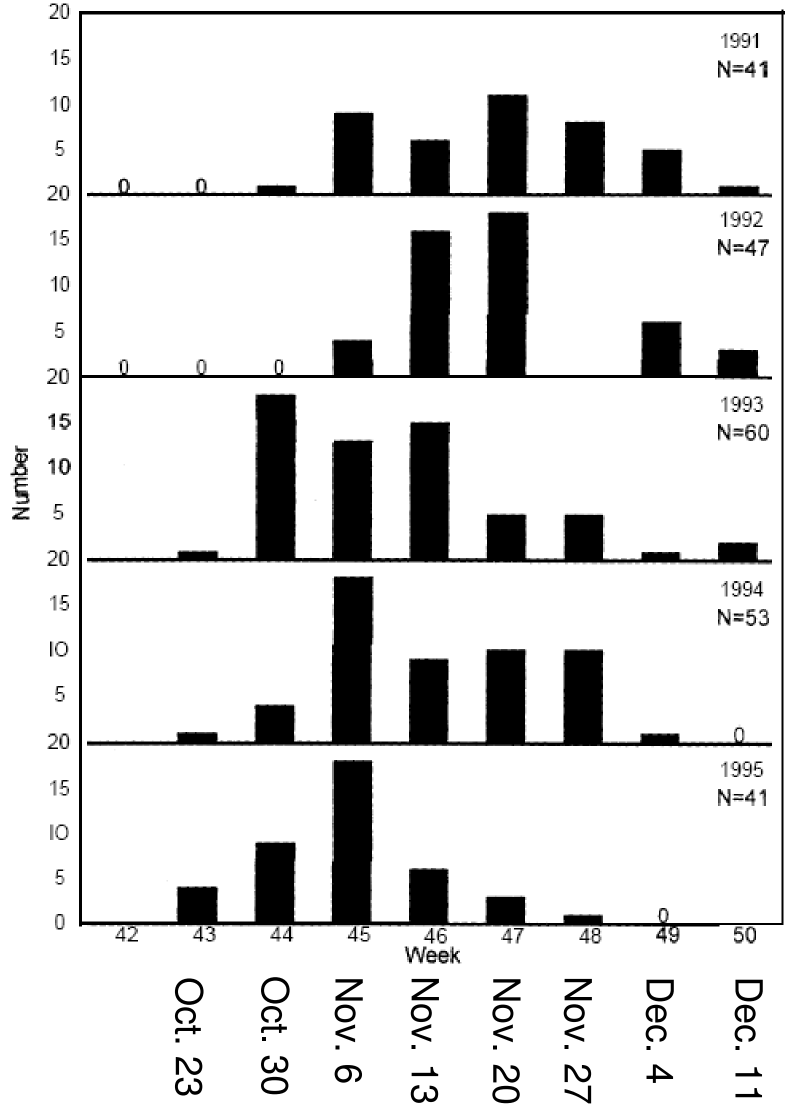


SUMMARY

27. Excellent spawning and rearing conditions for fall chinook salmon are present in the section of Snake River between upper end of Hells Canyon and Swan Falls, Idaho.

28. It appears from the information available that the spawning period of fall chinook salmon in the Snake River above Hells Canyon Dam site starts in late September or early October and is completed by early December.

1. Note: redds observed at time$_2$ are presumed to be unique and not duplicating those observed at time$_1$
Data from Zimmer (1950)



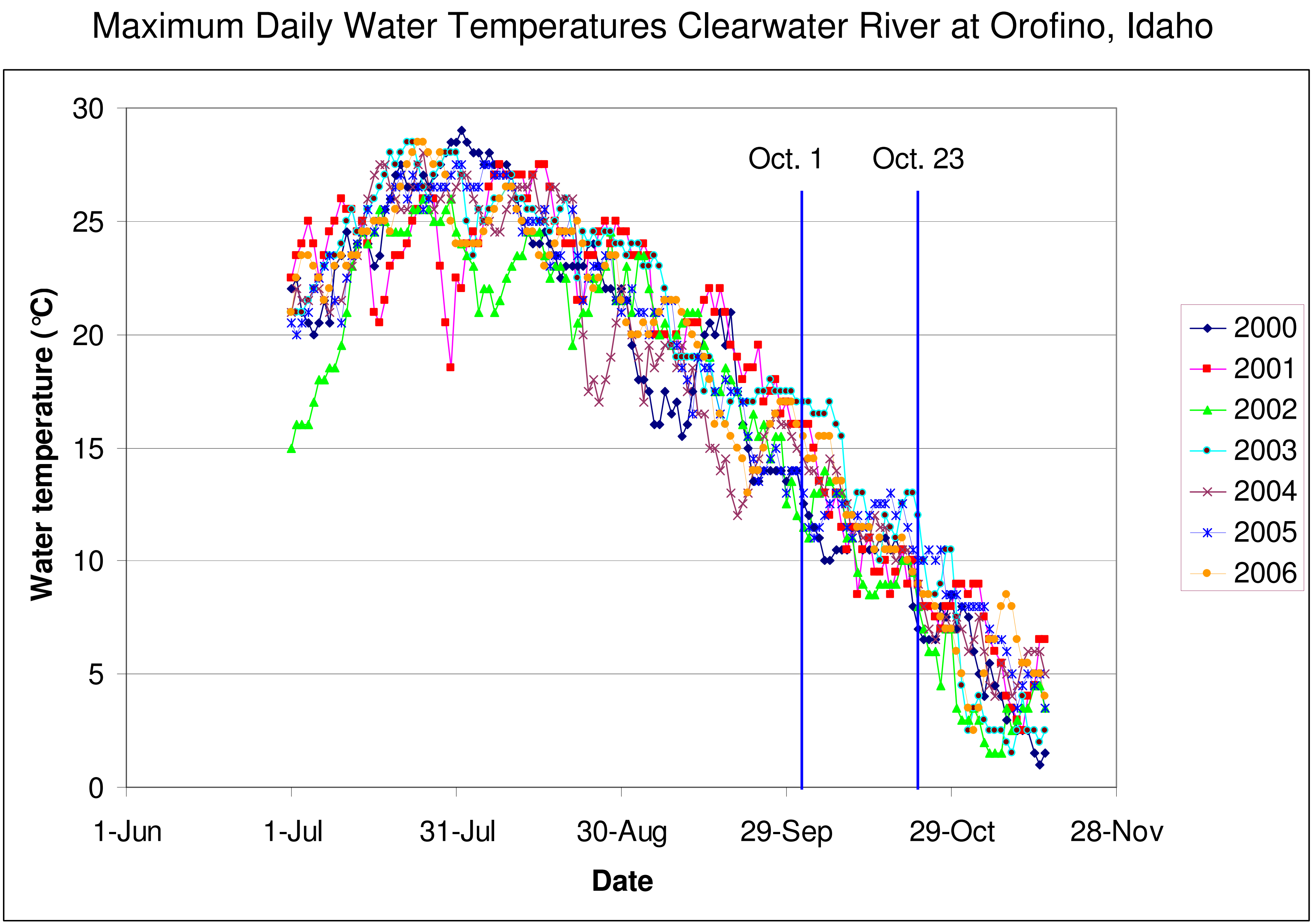
Redd counts- rkm 244 to rkm 396 (HCD)
Rondorf and Tiffan (1997)

Spawn Timing

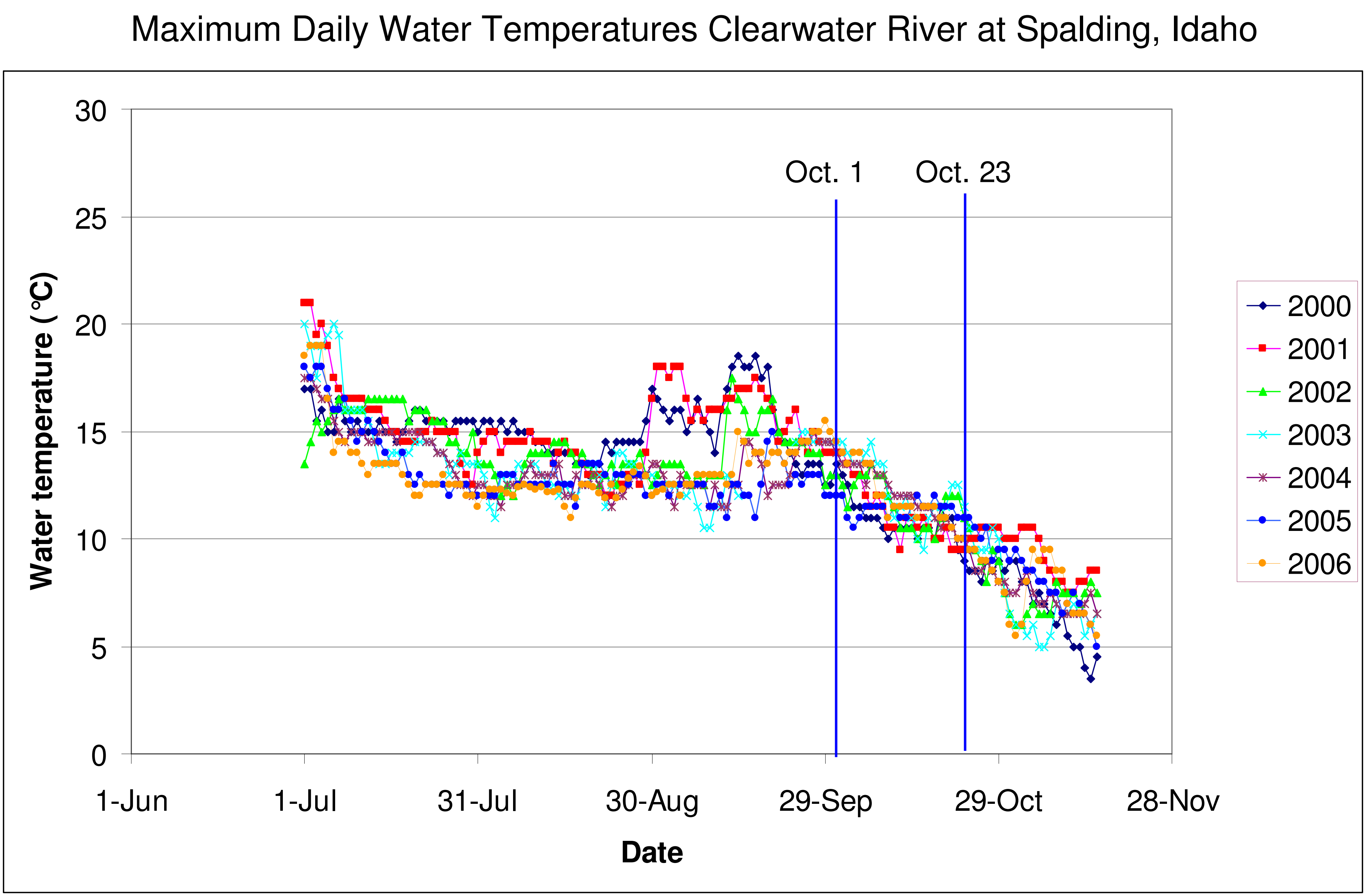
With the releases of cold water from Dworshak Reservoir on the North Fork Clearwater, water temperatures downstream in the Snake River have been significant reduced in the period from August 1 to October 23. Water temperatures on October 1 in the Clearwater River at Orofino ranged from approximately 12 to 17˚C, whereas at Spalding, Idaho they ranged from approximately 12 to 15˚C. Maximum August temperatures were as high as 28˚C at Orofino, but downstream at Spalding they were about 15˚C. In each case, water temperatures reached approximately 8 to 12˚C by October 23.

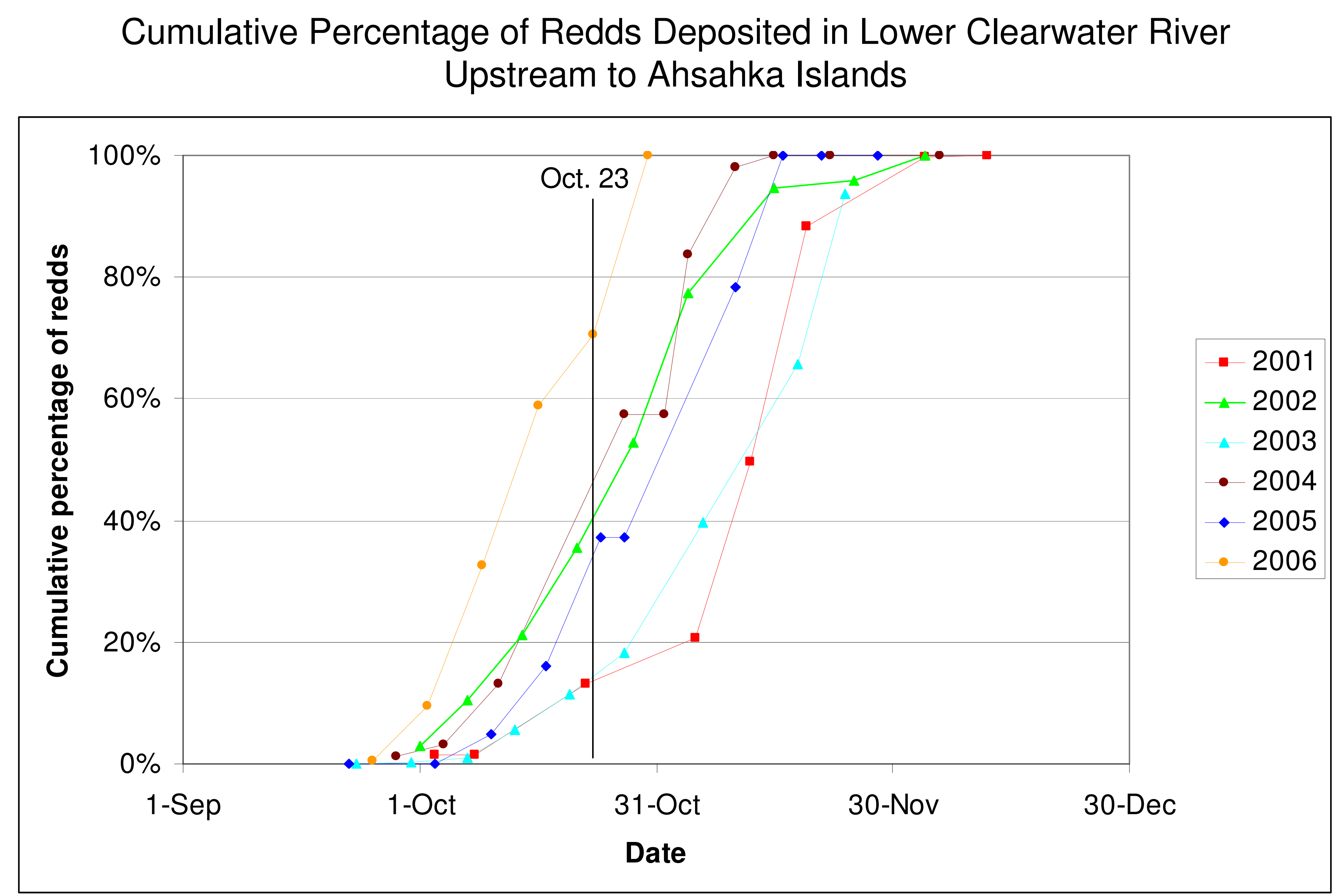
Since the release of water from Dworshak Dam into the lower Clearwater, the spawning time has commenced in late September in this river reach. Between 2001 and 2006, spawning has been 10 to 70% complete by October 23 (data from Nez Perce Tribe).

If a natural seasonal thermal pattern (NSTP) were re-established in the Snake River by ameliorating the thermal shift that has occurred, there is every reason to believe that spawning would be able to start earlier. In addition, adult survival and gamete viability would be more assured. There are no hatchery facilities that place their broodstock at risk by leaving them in holding ponds at temperatures approaching those found in the Snake River below Hells Canyon Dam.



Maximum Daily Water Temperatures Clearwater River at Orofino, Idaho
30
25
20
15
10
5
0
Water temperature (°C)
Oct. 1
Oct. 23
1-Jun
1-Jul
31-Jul
30-Aug
29-Sep
29-Oct
28-Nov
Date
2000
2001
2002
2003
2004
2005
2006


Maximum Daily Water Temperatures Clearwater River at Spalding, Idaho
Water temperature (°C)
30
25
20
15
10
5
0
Oct. 1
Oct. 23
1-Jun
1-Jul
31-Jul
30-Aug
29-Sep
29-Oct
28-Nov
Date
2000
2001
2002
2003
2004
2005
2006



Source: Nez Perce Tribe annual reports

Natural Seasonal Thermal Pattern (NSTP)

Oregon DEQ (2008) described in their water temperature standards implementation document what is meant by a natural seasonal thermal pattern (NSTP). This guidance illustrates that a NSTP requires that there be a natural pattern to use as a template. Although the NSTP that existed prior to the system of mainstem Snake River dams above the Hells Canyon Complex may not be known, the pattern reflected in the current inflow to Brownlee Reservoir and the 1956-1958 temperatures recorded at Central Ferry may a useful example. These examples both reveal that there has been an approximate 25-day shift in the annual maximum temperature and a similar shift in the entire seasonal decline in temperatures leading to the spawning period.

This shift in the NSTP would require that water temperatures be lowered starting about August 1. Also, with the cold water available in Brownlee Reservoir, there should be efforts applied to meet the summer water temperature standard.

CRITFC also believes that the water temperature standard of 13˚C should be met no later than October 23. In fact, it appears that in 1947 and 1948 that spawning commenced in late September, similar to the current lower Clearwater spawning pattern. Consequently, there is a case to be made to move the date of reaching 13˚C earlier. Also, the current practice of averaging the daily maximum temperatures from October 23-October 29 to arrive at a temperature of 13˚C is unacceptable. This gives several more days of non-compliance to IPC.

Natural Seasonal Thermal Pattern (NSTP)

Oregon DEQ. 2008. Temperature Water Quality Standard Implementation – A DEQ Internal Management Directive. Oregon Department of Environmental Quality. Portland, Oregon.

As an illustration, Figure 7-1 compares the seasonal temperature profiles of two rivers. In these profiles, the rising and falling slopes are very similar, peak widths are similar and timing of onset of temperature increases and decreases are nearly identical between River A and River B. If River A were representative of a natural seasonal thermal pattern, River B would reflect that pattern and would meet the natural seasonal thermal pattern requirements. In Figure 7-2, the seasonal pattern has been shifted below the reservoir, even though the maximum temperature has not increased.

Figure 7-1: Two Temperature Profiles

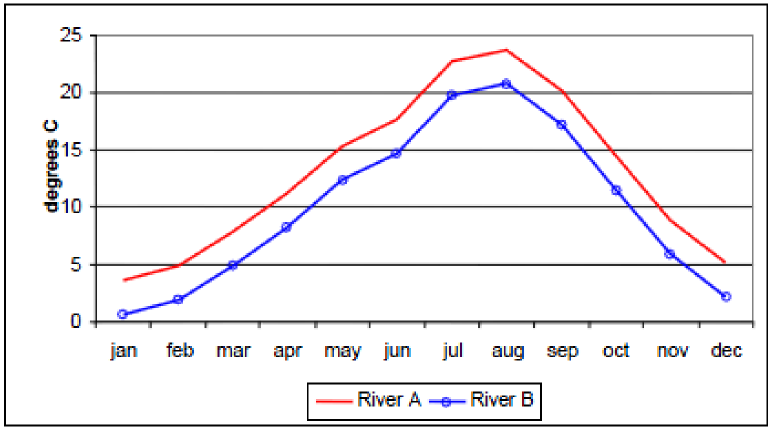
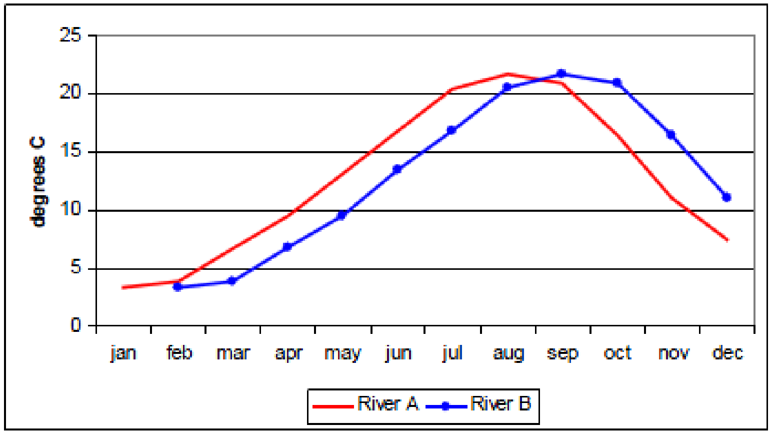


Figure 7-2: Shifted Seasonal Temperature Pattern

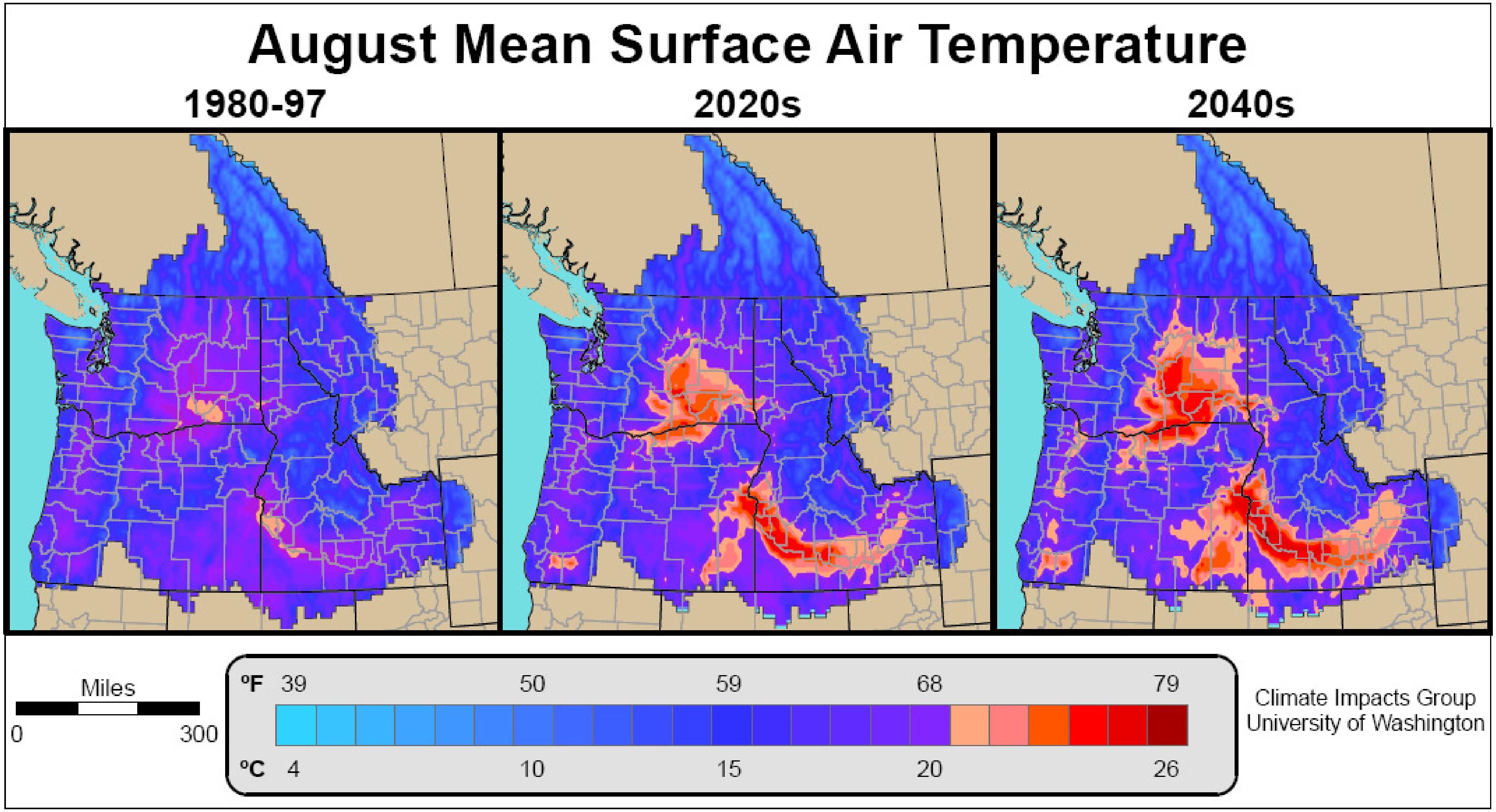


Climate Change--Future Trends

The upward trend in Columbia River water temperature maxima has been dramatic since 1939 as shown earlier. Future trends will be linked to projected changes in air temperatures. The University of Washington Climate Impacts Group has applied regional climate modeling to predict future August mean surface air temperatures across the Columbia and Snake basins. By 2040 the relatively hot August air temperatures will be pervasive throughout the Snake basin. This will surely continue to increase summer water temperatures.

The probable increases in summertime water temperatures in the Snake River mainstem will necessitate having management tools with near-term effectiveness to control water temperatures. This means that use of long-term upper basin riparian restoration will be ineffective within the life of the hydro-license agreement to reduce downstream water temperatures below Hells Canyon Dam. Although increased air temperatures may be accompanied by decreased water flows, it is under these conditions that colder water temperatures are available below the thermocline in Brownlee Reservoir (McCulloch et al. 2009). A TCS able to operate from August through October is likely the only means to bring about the correction of the NSTP, reduce summer temperature exceedances, and also meet the fall spawning standard.

McCulloch, A., C. Berger. and S. Wells. 2009. Brownlee Reservoir Cold Water Analysis and Downstream Impact of Cooler Water Temperatures Released from Hells Canyon Dam. Technical Report EWR-05-09. Water Quality Research Group, Department of Civil and Environmental Engineering, Maseeh College of Engineering and Computer Science, Portland State University
Portland, Oregon. 34p.



Recent and Projected Average August Surface Air Temperature in the Columbia Basin. The left panel shows observed August temperatures in the Columbia River Basin. Future temperature projections made with a relatively cool climate model are shown in the center and right panels.